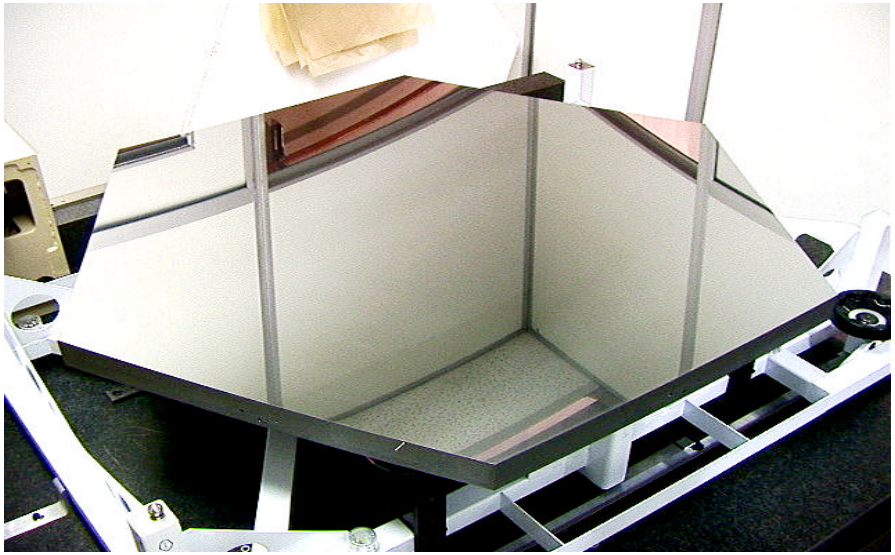
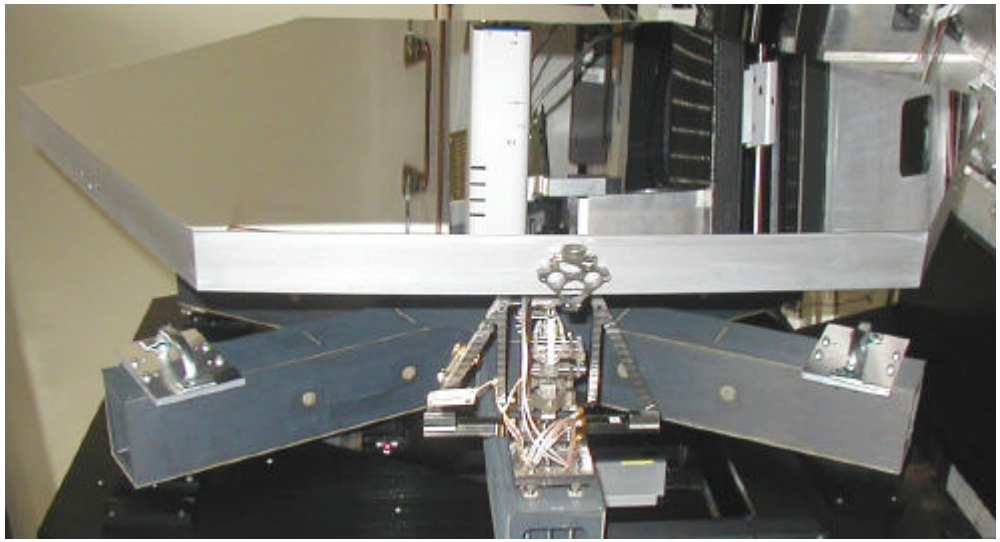
Ball Advanced Mirror System Demonstrator (AMSD) Overview

Beryllium Semi-rigid Mirror

August 2003

Overview of Ball's Beryllium AMSD Design



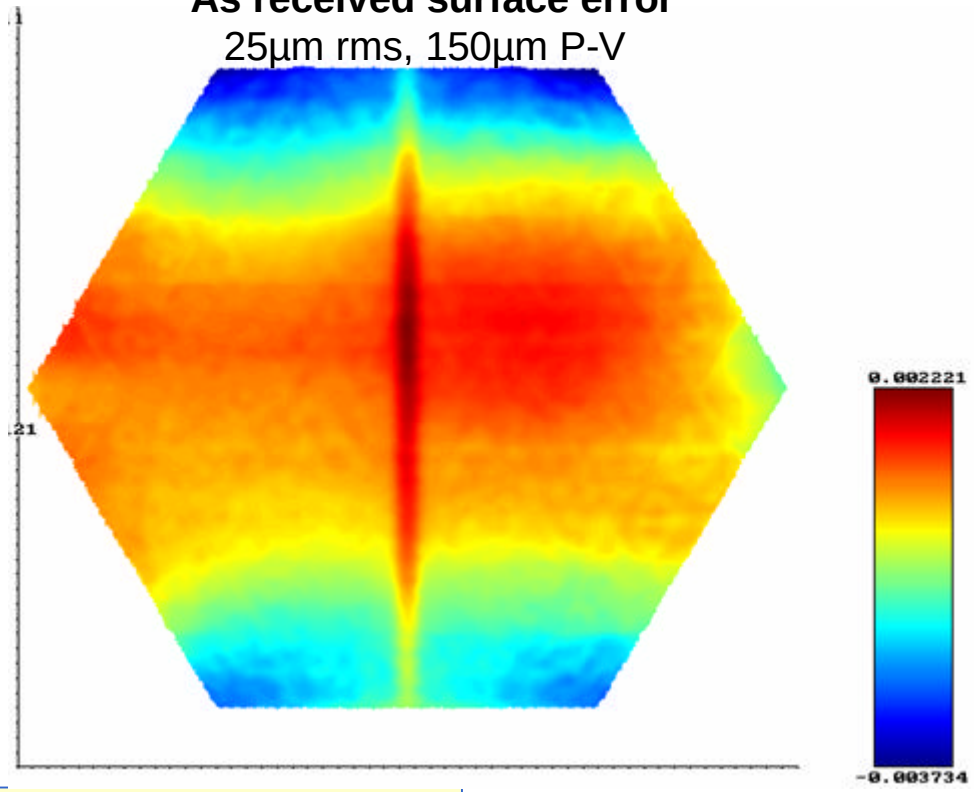


- **1.39 m point-to-point light-weighted beryllium semi-rigid mirror**
- **10.3 kg/m^2 beryllium substrate areal density**
- **15.6 kg/m^2 areal density for mirror system including mirror, reaction structure, flexures, actuators**
- **Optical and physical characteristics traceable to JWST**
- **Benefits from "lessons-learned" on Sub-scale Beryllium Mirror Demonstrator (SBMD), which achieved 19 nm, rms, surface at 38K**

Beryllium Mirror Processing and Testing History

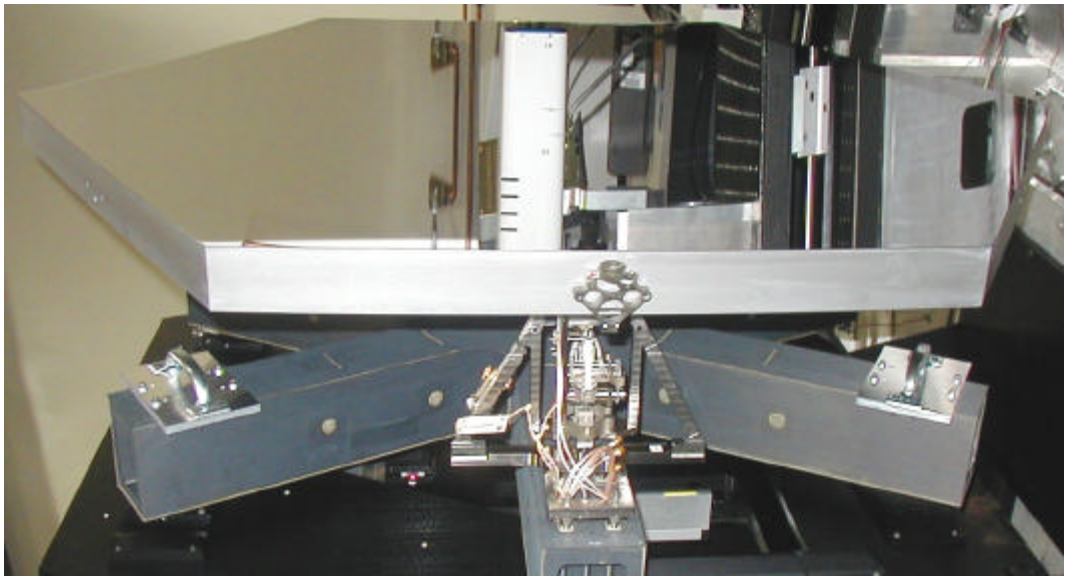
AMSD Mirror Manufacturing - Handoff From Machining to Polishing

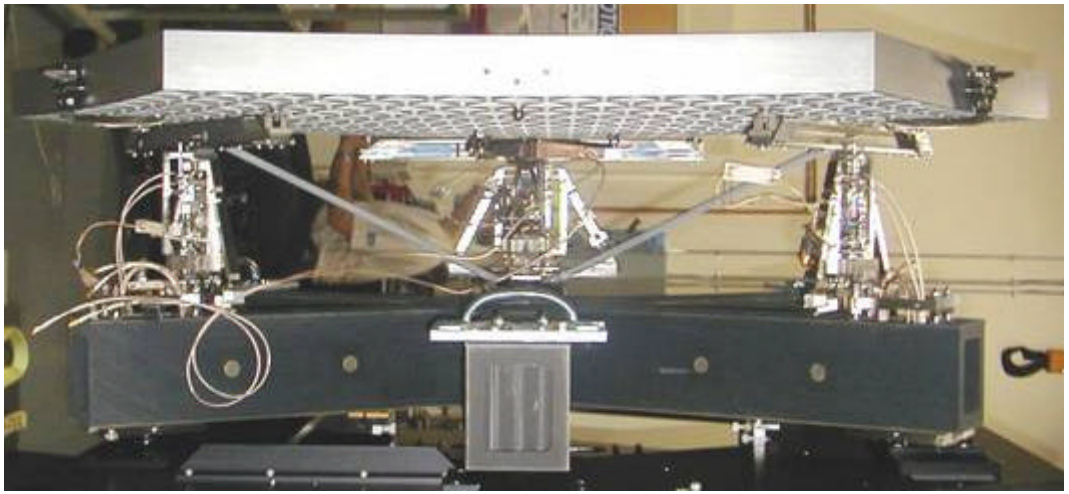
As received surface error
25µm rms, 150µm P-V



Mirror blank machined at Axsys and then shipped to Tinsley for polishing

Beryllium AMSD System Integration and Ambient Optical Test Complete 6/27/03





Integrated Mirror Assembly Figure is 70 nm-rms

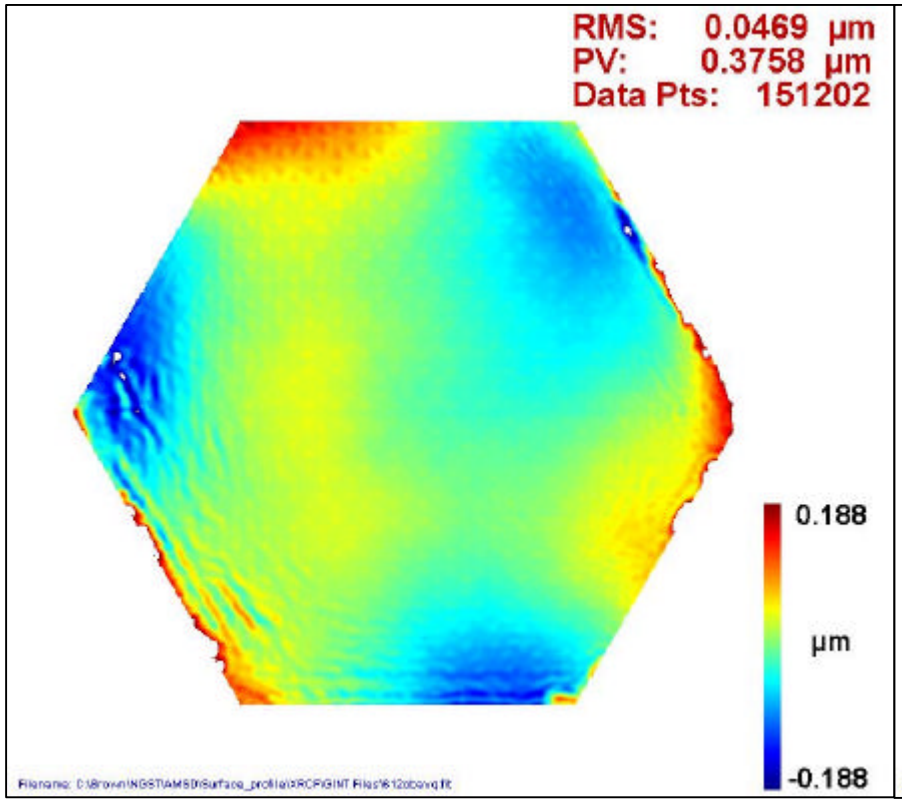


Figure Prior To System Integration

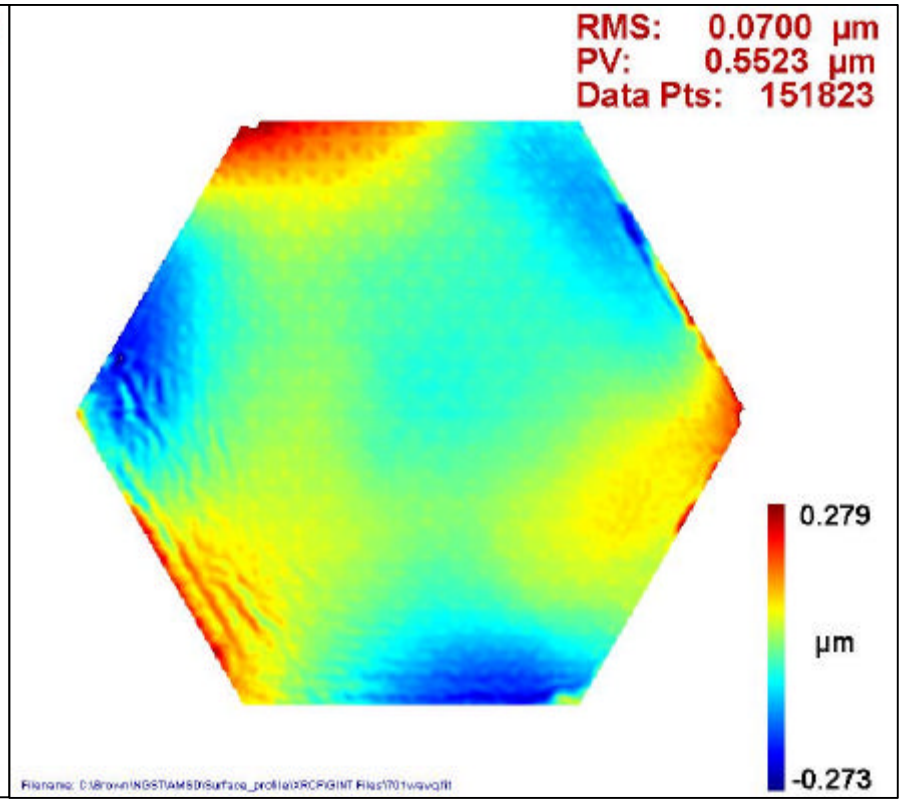
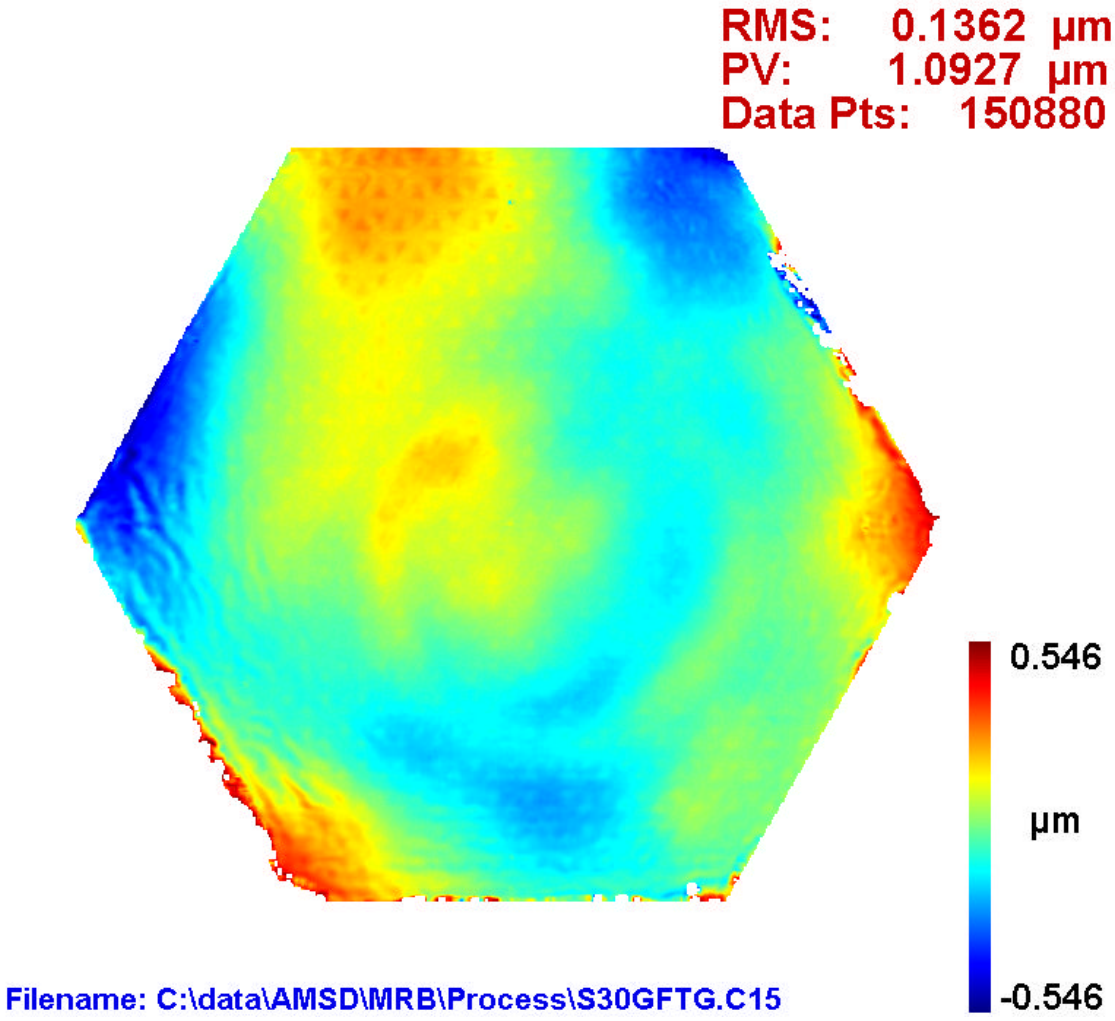


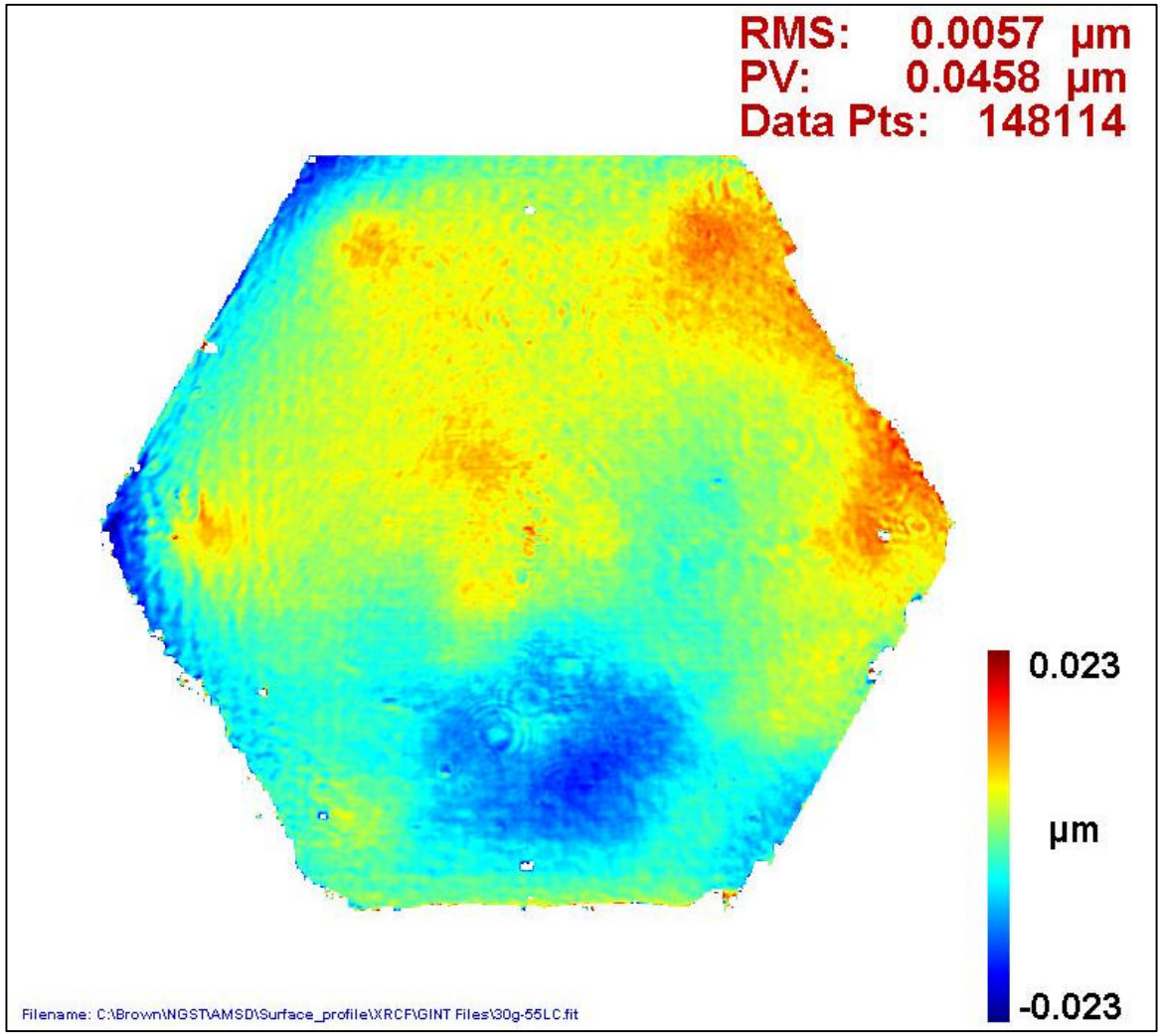
Figure After System Integration

Beryllium AMSD Mirror In XRCF Chamber, July 7, 2003

Integrated Mirror Assembly Figure at 30 Kelvin is 136 nm-rms



Measured Performance from 30 to 55 K is Stable Over Operational Temperature Range

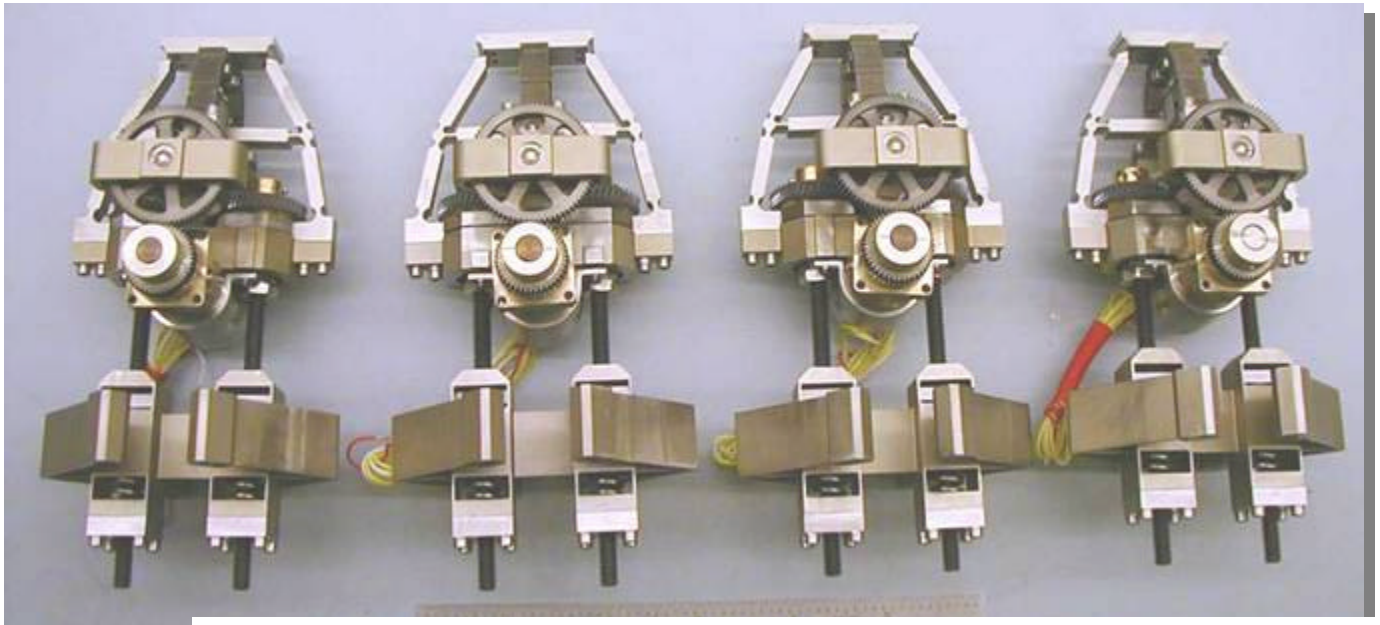


The fully integrated beryllium mirror assembly figure is stable across the entire expected JWST operating temperature range

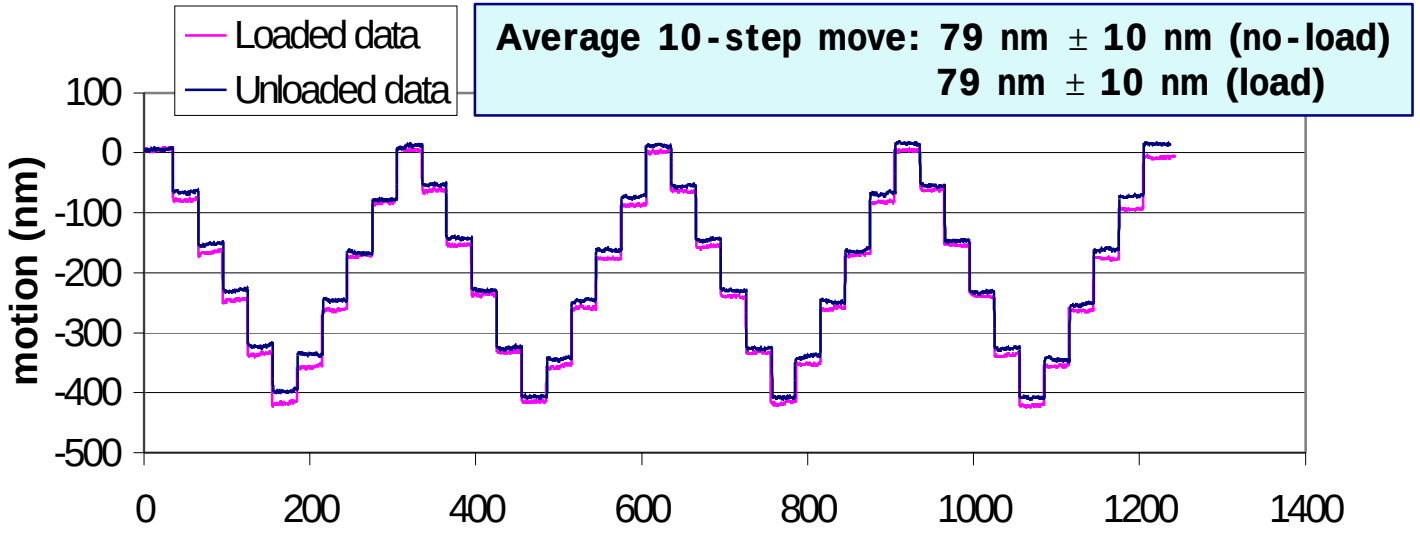
Note that the 5.7 nm, rms, value includes measurement errors as well as figure change

Cryogenic Nan-positioning Actuator Development

AMSD Position and Figure Control Actuators



- Cryogenic nano-positioning actuators developed by Ball IR&D
- Design matured for AMSD and traceable to JWST design



Technology Development

Primary Technology Challenges

The beryllium AMSD program's goal was to mitigate the major challenges in producing mirrors for the JWST program. The following charts highlight how these challenges were addressed.

- **Mirror geometry**
  - Size, Shape, Areal density,
  - Stiffness/flexibility
- **Surface figure**
  - TSE
  - RoC adjustment
- **Actuator**
  - Step size, Range, Repeatability
  - Cryogenic operation
- **Reaction structure**
  - Mirror support and stiffness
- **Mirror system challenges**
  - Mirror to reaction structure differential CTE accommodation
  - Frequency requirement
  - Optical testing with horizontal optical axis at MSFC

AMSD Program Successfully Addresses Mirror Geometry Challenges (Backside)

- **Billet production**
  - AMSD has largest HIPed beryllium blank produced by BWI
    - Size and geometry selected for compatibility with existing facilities
- **Blank production**
  - 10.6 Kg/m^2 blank lightweight produced
  - Pocket details traded against machining parameters
    - Increased corner and fillet radii
  - Mirror flexibility during profile machining
    - Refine mirror mounting and metrology techniques during machining

AMSD Program Successfully Addresses Front Surface Figure Challenges

- **Blank production**
  - Mirror mounting and metrology during profile machining
    - Refined mirror mounting and metrology techniques during machining
- **Mirror polishing**
  - Polishing process demonstrated on SBMD and SIRTF
  - Understanding of mirror mounting issues critical to success
    - Repeatability of surface figure on mount
      - Mirror attachment hardware installed prior to final polish
      - Establish repeatable boundary condition between mirror and mount
    - Improved understanding of cryogenic deformation
      - Elimination of mount-dependent effects minimizes cryo-null figuring
- **Radius of curvature adjustment**
  - RoC adjustment techniques demonstrated on SBMD
  - NASTRAN modeling used to predict low residual error after adjustment

AMSD Program Successfully Addresses Actuator Challenges

- **Our AMSD system design recognizes the inherent risk in relying on mechanism performance**
  - Our figure control uses a single actuator per segment
- **Range, Resolution, Repeatability**
  - Knowledge of position during fine stage adjustments
    - Ball performed extensive testing on IR&D actuators to understand step size and hysteresis
- **Cryogenic Operation**
  - Actuator development program eliminates risk of failure at cryo
    - IRAD and AMSD actuators experienced significant cryogenic testing
  - Mirror mass loading changes actuator performance character
    - AMSD actuators tested in ambient and cryogenic environment with axial tension and with lateral load, as well as, unloaded

AMSD Program Successfully Addresses Reaction Structure Challenges

- **Cryogenic performance**
  - Reaction structure distortions that might cause mirror figure error have been controlled
  - Risk of composite delamination mitigated
    - Thermal cycled reaction structure independently at MSFC to verify integrity

AMSD Program Successfully Addresses Mirror System Challenges

- **CTE differential between mirror and reaction structure**
  - Distortion of mirror during cryogenic operation
    - Flexure system designed to limit mirror deformation during cooldown
    - Mount optimized for cryogenic operation, decouples reaction structure distortions from mirror figure error
- **Mirror system frequency requirements**
  - Simultaneously satisfying ambient and cryogenic operational requirements
    - Stiff support system required for ambient operation
    - Soft support system implemented for cryogenic operation
- **Optical axis horizontal during testing**
  - Deflections produce bias term to be subtracted from measured data
    - Gravity compensation techniques developed on SBMD
      - Low deflection support used for component testing
      - In-process model validation ties measured data to analysis results
      - Measurements at multiple orientations at both component and system level